SOUND TRANSIT

HCT Planning

Sound Transit 2

Benefit-Cost Analysis Methodology Report

with Analysis Results

Prepared for:
Sound Transit

Prepared by:
PB Consult

In association with:
Parsons Brinckerhoff

2008 UPDATE (DRAFT)

May 2008

TABLE OF CONTENTS

LIST OF EXHIBITS

INTRODUCTION

Sound Transit is in the process of developing a second phase of major transit investments to take before the voters for a funding ballot in 2008. A step in this process involves conducting a benefit-cost (B/C) analysis of the proposed investment package for consistency with the Puget Sound Regional Council's overall transportation plan.

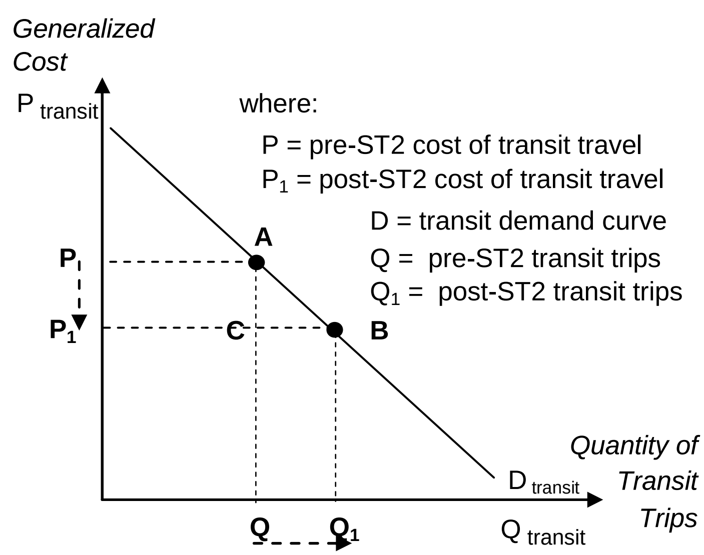
As such, this report reviews the state-of-the-practice in performing B/C analysis for transit investments in the United States. In addition, the review identifies the universe of benefits and costs potentially quantifiable for consideration in the Sound Transit Phase 2 B/C analysis, as well as procedures for estimating/quantifying them.

Based on the review of current practice and an assessment of available information from the existing Sound Transit and Puget Sound Regional Council (PSRC) demand models, the report proposes an approach and methodology for conducting a B/C analysis of the Sound Transit Phase 2 (ST2) investments. The proposed approach identifies benefits to be considered/quantified, procedures for doing so, data requirements from existing sources, capital, operating and maintenance cost data requirements, and key analysis assumptions and justifications for those assumptions.

BACKGROUND AND CURRENT PRACTICE

The basic paradigm for estimating benefits, used almost universally in transportation B/C studies, is consumer surplus. People will travel to a destination using their selected mode when the overall cost of travel is less than or equal to the benefit of travel, where the benefit is essentially the maximum cost that they would be willing to incur for that travel. When the cost is less than this "willingness to pay", the difference between the two is referred to as the "consumer surplus". It represents the benefit of travel above and beyond the required cost. This concept as it relates to transit is illustrated in Exhibit 1.[1]

Exhibit 1 — Change in Transit Consumer Surplus due to Reduced Cost of Transit Use



The downward sloping line *D* represents the travel demand curve or function for transit — at lower generalized travel costs, people travel more often and/or more people travel via transit. In this example, the existing transit infrastructure would accommodate *Q* trips at generalized travel cost *P* (travel time plus out-of-pocket costs) prior to the ST2 investments. The area above *P* and below the demand curve *D* represents the collective

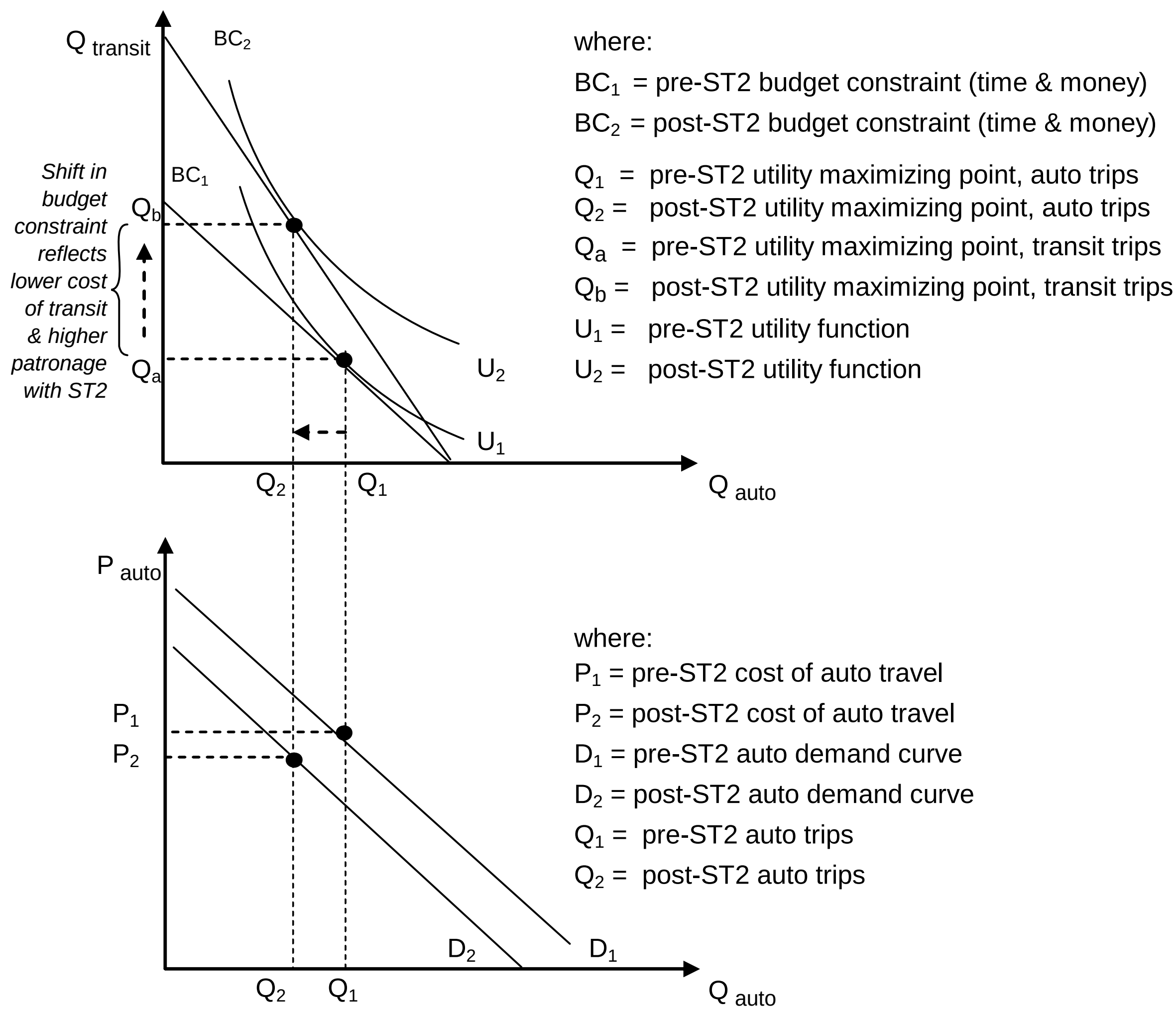
[1] Exhibit 1 and the ensuing discussion of consumer surplus assume constant returns to scale.

costs that users are willing to incur above and beyond what they have to spend for travel level *Q*. This area represents the benefit or "consumer surplus" of transit travel at levels *P* and *Q*.

After the proposed ST2 investments, the marginal cost of transit travel falls from *P* to P_1, reflecting reduced overall travel time, reduced out-of-pocket costs, or new transit service in areas which did not previously have transit. As the cost of using transit declines and more people use transit, there are more opportunities in which transit use is economically attractive and the number of transit trips generated increases from *Q* to Q_1. Area $PABP_1$ is the increase in consumer surplus, which includes gains to both existing riders/level of travel *Q* (the rectangular area bounded by $PACP_1$) in the form of lower costs (e.g., time savings) and the benefits to new transit riders/additional travel Q_1 minus *Q* (the triangular area bound by *ABC*).

For comparison, Exhibit 2 illustrates the pre- and post-transit investment impacts on auto travel demand and the corresponding changes in consumer surplus from the mode shift to transit.

Exhibit 2 — Change in Auto Consumer Surplus due to Reduced Cost of Transit Use



Long term gain in consumer surplus (auto) = (P_1 - P_2) x Q_2, resulting from reduction in cost of auto travel for existing auto users, due to reduced congestion from mode shift to transit.

The top graph in Exhibit 2 shows a median traveler's utility function (U_1) subject to a transportation time and monetary budget constraint (BC_1), and how the modal split would change when the

generalized cost of transit use decreases due to the ST2 investments. The resultant mode shift to transit with ST2 is reflected in BC_2 (at a lower cost, utility is maximized with more transit trips and less auto trips). The change in transit trips from Q_a to Q_b matches that shown for the transit demand curve in Exhibit 1. The bottom graph in Exhibit 2 shows the impact on the demand for auto travel as the transit mode is substituted for some auto trips. This is represented by the inward shift in the auto demand curve, which reflects that at any given price or cost for auto travel, there would be a lower level of auto trips after the ST2 improvements. The mode shift from auto to transit combines with the decline in highway congestion to lower the overall cost of auto travel for those trips that remain. The net gain in consumer surplus or benefit to remaining auto travel is represented by the area calculated as $(P_1 - P_2) \times Q_2$.

To actualize the consumer surplus concept, B/C analysis is largely dependent on the outputs generated from travel demand models, which typically produce data in the form of matrices of trips, times, and costs on the network. In practice, this involves outputs for a 'no action' case, which then becomes a basis of comparison from which to measure the changes in consumer surplus attributable to the alternative case with transit improvements. In measuring the direct benefits to transit users, the consumer surplus calculations are made for transit trips by origin-destination (O-D) pair. Other mobility benefits are primarily estimated as functions of the highway O-D matrices or trip tables, vehicle miles traveled (VMT) data, and model input assumptions.

Note that by assuming a linear demand curve over the range of change in travel costs (P to P^1), gains in consumer surplus (CS) accruing to transit users from reduced transportation costs and increased ridership can be estimated as the area of rectangle, $PACP^1$ (gains to existing riders) plus the area of triangle ABC (gains to new transit riders). The formula for this is:

$$\Delta \text{CS} = \underbrace{[\,(P - P^1) \times Q\,]}_{\textit{Rectangle Portion}} + \underbrace{[\,\tfrac{1}{2} \times (P - P^1) \times (Q - Q^1)\,]}_{\textit{Triangle Portion}}$$

For the ST2 investments, the Sound Transit and PSRC travel demand models will be used to estimate transit and highway user benefits, respectively, relative to the case without the ST2 investments. Note that because current travel demand models are only capable of counting "new riders" as those who shift from other modes, it will likely underestimate transit user benefits by not also accounting for "induced trips". In reality, the ST2 investments are also likely to increase the overall level of travel within the region because they will increase accessibility and potentially generate some trips that would otherwise not be made.

There are also indirect mobility benefits to the rest of the system, primarily highway user benefits generated due to some highway travelers shifting modes to transit.[2] The analysis assumes that benefits for travelers who continue to use the highway network include improved travel times/mobility, vehicle operating cost (VOC) savings, parking cost savings, and highway accident reduction savings (these benefits are discussed later in the paper).

Though not necessarily recognized by individual users in their own actions, societal benefits may also be accounted, and include savings in the societal/external cost of highway accidents and savings

[2] In this report, "highway" collectively refers to the interstate, highway, arterial, and local street networks.

in environmental costs such as air pollution. Because these benefits are primarily associated with reduced automobile travel or less congestion, an implicit assumption is that new highway trips are not induced by the ST2 investments directly or indirectly through alleviating highway congestion via mode shift. This will be discussed in more detail in the following section. Exhibit 3 summarizes these three categories of benefits.

Exhibit 3 — Categories of Benefits

Direct Transit User Benefits	***Indirect Highway System User Benefits***	***External/Societal Benefits***
The economic value of changes in consumer surplus (for both existing and new transit riders)	The economic value of congestion reduction impacts within the highway network due to mode shift to transit	The net economic value of reduced pollution, noise and energy use arising from changes in travel behavior

KEY ANALYTICAL ASSUMPTIONS

Several analytical and procedural assumptions are required to apply B/C analysis methods to the available data and unique conditions regarding the proposed ST2 rail investments. The following outlines these assumptions and their basis.

1. Real Discount Rate

Benefits and costs are typically valued in constant (e.g., 2007) dollars to avoid having to forecast future inflation and escalate future values for benefits and costs accordingly. Even in cases where costs are expressed in future, year of expenditure values, they tend to be built upon estimates in constant dollars, and are easily deflated. The use of constant dollar values requires the use of a real discount rate for present value discounting (as opposed to a nominal discount rate).

A real discount rate measures the risk-free interest rate that the market places on the time value of resources after accounting for inflation. Put another way, the real discount rate is the premium that one would pay to have a resource or enjoy a benefit sooner rather than to have to defer it until later. For example, most people would prefer and thus, place a higher value on taking a vacation now instead of waiting ten years into the future, illustrating the preference for having a resource (vacation) or the choice to have it sooner rather than later. As such, the values of future resources must be discounted.

For a given evaluation period, U.S. government securities of similar maturity provide an appropriate estimate of the time value of resources reflected in a real discount rate, where the real rate is a "Treasury Inflation-Indexed" bond of the same maturity. Historically, this risk-free real interest rate has generally been within the range of 2.0 to 4.0 percent, and at present, is at the low end of this range (1.88%).[3]

[3] Source: Bloomberg (2008).

For ST2 investments, all benefits and costs will be expressed in constant 2007 dollars. The cost estimates already reflect this assumption. Figures used to calculate the dollar values of benefits that are based in other (historical) years will be converted to 2007 dollars using the Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) as estimated for the Seattle-Tacoma-Bremerton metropolitan statistical area (MSA).

Choosing an appropriate discount rate is essential to appropriately assessing the costs and benefits of a project. The higher the discount rate, the lower the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value or economic feasibility of the investment.

Exhibit 4 illustrates some real discount rates – ranging from 2% to 5% – that have been recommended or used in recent B/C analyses in the U.S. It is based on a survey of industry guidance and recent studies.[4]

The proposed real discount rate for evaluating the ST2 investments is 3.0%. This value is consistent with other studies, and given current interest rates for risk free investments in the present economy, the 3.0% real discount rate may even be regarded as somewhat high, and thus conservative in terms of estimating the present value of future benefits.

Exhibit 4 — A Survey of Real Discount Rates

Real Discount Rate	Year	Location	Source
3.5%	2003	U.S. (AASHTO Guidance)	A Manual of User Benefit Analysis for Highways, 2nd ed.
4.5%	2003	Minnesota	Northwest Corridor BRT: Replication Analysis
2.0%	2003	Minnesota	Northwest Corridor BRT: Best Practice Analysis
3.5%	2004	Washington	Congestion Relief Analysis Project
3.2%[5]	2004	California	Methodology for Discounting Benefits and Costs for Transport Projects in California
3.0%[6]	2006	U.S.	OMB Circular No. 94 (appendix C)
5.0%	2006	Wisconsin	Socioeconomic Benefits in Transit: C-B Analysis

[4] See the citations for AASHTO (2003); Parsons Brinckerhoff (2003); Parsons Brinckerhoff (2004); Caltrans (2004); Office of Management and Budget--White House (revised 2006); and HDR/HLB Decision Economics Inc. (2006).
[5] For a 30-year evaluation period (http://www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost/calculations/discount_rate.html)
[6] For a 30-year evaluation period (http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html)

2. Evaluation Period

Benefits and costs are typically evaluated for a period that includes the construction period and an operations period ranging from 20-50 years after the initial project investments are completed. Given the permanence and relatively extended design life of rail transit investments, longer operating periods, and thus, evaluation periods are often used. However, beyond 50 years, the ability to forecast meaningful future benefits and costs is questionable, and any such values contribute increasingly less to the results, given the high degree of present value discounting this far into the future.

For the ST2 B/C analysis, the proposed evaluation period includes the relevant (post-design) construction period during which capital expenditures are undertaken, plus 40 years of operations beyond project completion within which to accrue benefits. A sensitivity test assesses what an additional 10 years of operations would contribute to the findings.

For the purposes of this study, it has been assumed that construction of the ST2 investments will begin in the year 2012 and will be completed and fully operational by the end of 2020. As a simplifying assumption, all benefits and costs are assumed to occur at the end of each year. Since some investments will come on-line in an incremental manner prior to 2021, thereby generating benefits and operating costs prior to the project being fully operational, a three-phase approach to the calculation of the annualized B/C is proposed. Exhibit 5 provides a description of each of the three phases.

Exhibit 5 — Proposed Evaluation Period Phases

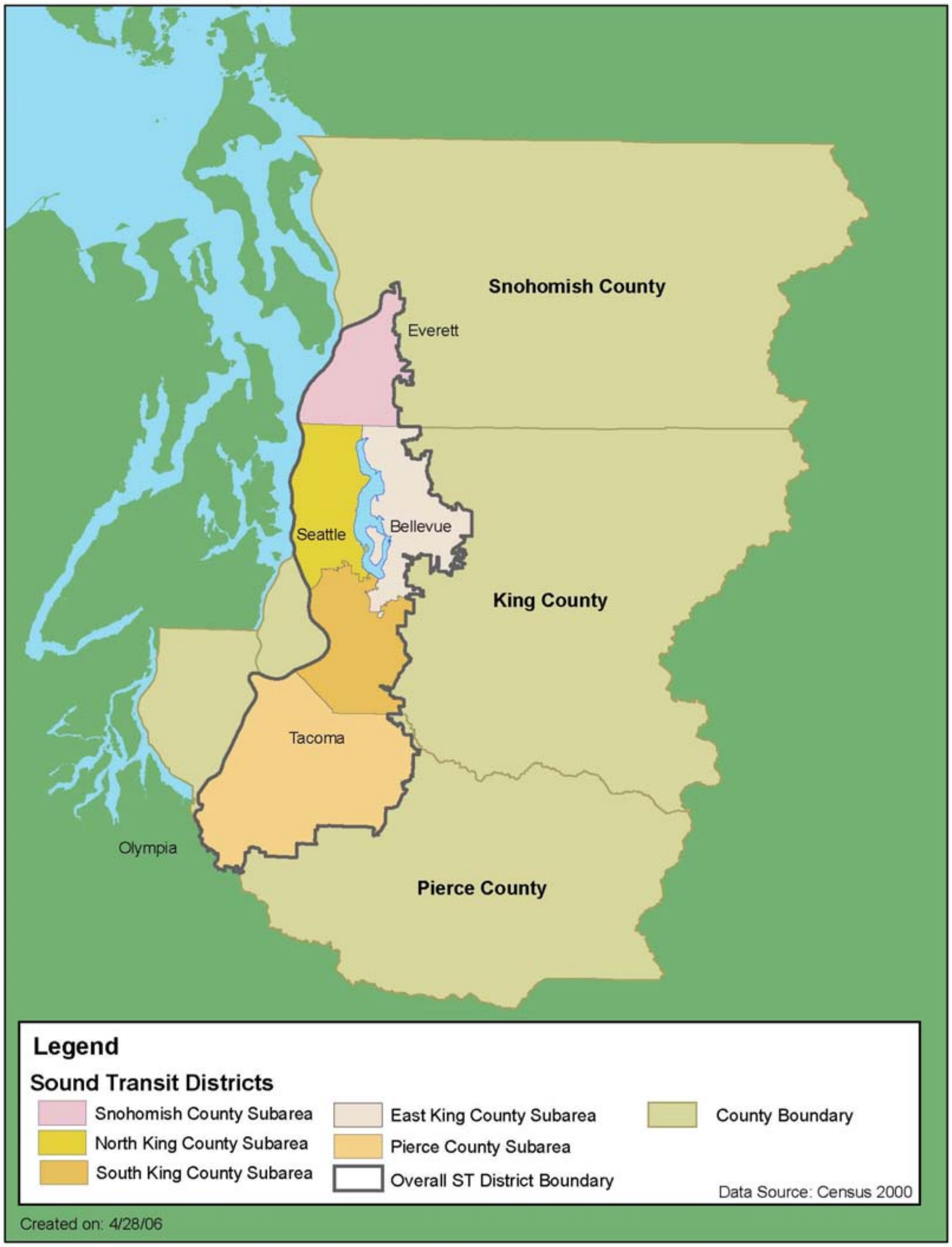
Stage 1:	**Timeline**	- from 2012 through 2018
	Benefits	- none
	Costs	- yearly construction capital costs (construction costs incurred prior to 2012 will be uniformly distributed among years 2012-2015); some commuter rail operating and maintenance (O&M) costs for service additions not modeled for benefit estimation prior to 2020
Stage 2:	**Timeline**	- from 2019 through 2020
	Benefits	- escalating partial benefits (as a simplifying assumption, in 2019, 1/3 of full benefits will encapsulate the partial benefit for that year; and in 2020, 2/3 of full benefits will encapsulate the partial benefit for that year).
	Costs	- yearly construction capital costs; only ramp-up O&M costs.
Stage 3:	**Timeline**	- from 2021 through 2060
	Benefits	- full benefits
	Costs	- full O&M costs; periodic replacement & rehabilitation expenditures; and residual value (negative) costs at the end of the evaluation period.

3. Study Region Definition

The geographic coverage of the ST and PSRC travel demand models dictates the study region for the ST2 B/C analysis. While the ST service district represents the urbanized subset of King, Pierce and Snohomish Counties, for purposes of measuring mobility benefits, the entire three-county region becomes the defined area for which the models outputs apply. Benefits from the ST2

investments extend beyond the ST boundaries to the three county region, insofar as some transit trips may originate from outside the ST boundaries (traveler drives to a park-and-ride lot within the service area) and highway mobility benefits from the transit mode shift impact auto trips originating outside the ST service area. As such, the ST2 B/C analysis proposes to consider the three-county area shown in Exhibit 6 as the study region from which to measure benefits and costs.

Exhibit 6 — Study Region Map

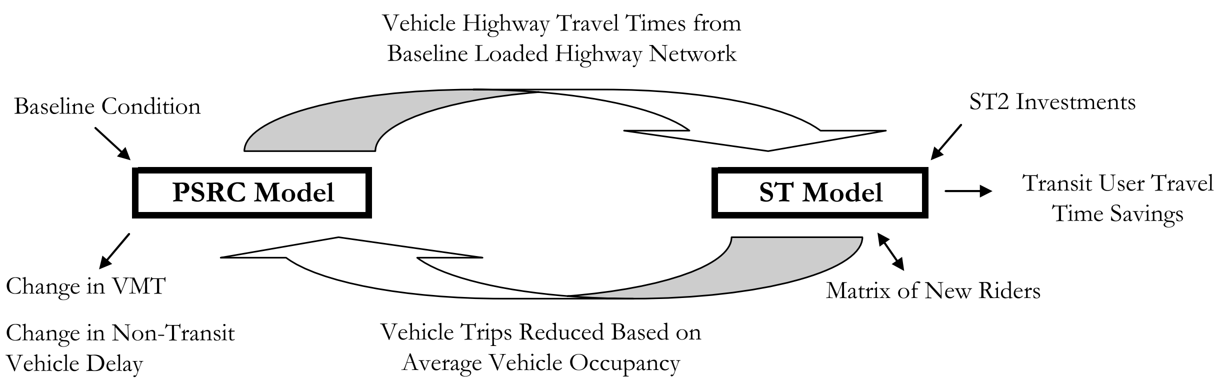


4. Travel Data Sources and Forecast Years for Transit and Highways Benefits

Travel Demand Models

The Sound Transit and PSRC travel demand models are used in tandem to forecast future travel patterns by mode, and to estimate transit and highway user benefits, respectively. The ST Transit model provides the transit ridership and cost data for calculating direct transit user benefits as changes in travel time between the ST2 investment case and the no-build basis of comparison. Exhibit 7 provides a graphical summary of how the two models are linked together to provide multi-modal travel data.

Exhibit 7 — ST and PSRC Model Linkages for Producing Multi-Modal Travel Data



The interchange between the ST and PSRC models did not take into consideration any feedback loop through trip distribution. This was primarily to minimize likely randomness effect in estimating change in VMT and vehicle delay measures due to non-convergence in the highway assignment process. This particular limitation in the current models has been acknowledged by FTA for not being able to predict reliably benefits of highway congestion relief – in both their magnitude and their geographic location with respect to a transit project. The magnitude is especially unpredictable if the assignment results are used for subtractions between alternatives with relatively minor differences in super-congested future networks.

In summary, baseline highway conditions including travel times from the PSRC model are fed into the ST model. This results in differing travel behaviors before and after the ST2 investments, from which the change in consumer surplus or transit user benefits may be calculated. To the extent that the ST2 investments cause a mode shift from autos to transit, person-trips using autos (and hence, vehicle-trips) will be reduced. The reduction in vehicle trips is fed back to the PSRC model to provide overall changes in VMT at an aggregate link level, and the change in (non-transit) vehicle travel times due to improved flow conditions. These outputs form the basis for calculating the indirect and external benefits of the transit investments, which are covered in detail in the next section.

Time Periods, Forecast Years, and Discounting/Extrapolation Assumptions

Forecasts of travel demand associated with ST2 have been performed by Sound Transit for future years 2020 and 2030. Accordingly, it is assumed that the underlying benefits from transit investments will be linearly interpolated between 2020 and 2030, and similarly extrapolated back to 2019. To account for the phased implementation in 2019 and 2020 (as noted in Exhibit 5), benefits will be subsequently factored by 1/3 in 2019 and 2/3 in 2020.

Travel demand forecasting analysis performed by Sound Transit for ST2 indicates that the expected annual growth rate for transit ridership – independent of any transit service improvements or change in travel conditions – is 1.7% per year from 2004 to 2030. About 1.2% is attributable solely to population and employment growth, and the other 0.5% to increases in highway delay and associated costs. Although the underlying growth in transit ridership (controlling for transit service improvements) of 1.7% per year may continue for the foreseeable future, the analysis conservatively assumes that beyond 2030, benefits only grow at three quarters of that rate, or 1.3% per year,. The conservative assumption is made to reflect the additional uncertainty associated with growth in more distant years and the possibility of distant future regional growth being less than the rate predicted for the current planning horizon.

5. Highway Impacts of Mode Shift to Transit

ST2 investments are expected to encourage some auto travelers to switch to transit (i.e., cause a mode shift from highway to transit travel). Under congested highway conditions, one or both of two reactions might occur. The first is that the new auto "spaces" in the highway network created by fewer auto trips would improve traffic flow and speed conditions, thereby generating time savings for the remaining highway users and creating other benefits associated with reduced VMT. The second is that latent demand would fill the vacated highway spaces with new auto trips—increasing the overall number of trips in the region—and the level of highway congestion would not change in the long term. New (induced) auto trips would occur because the generalized cost of travel would be lowered in the short term, and the value of travel for new highway users would equal or exceed their cost of making a trip.

If the analysis were to recognize that the vacant spaces would be filled by new auto users, it would not be appropriate to also include benefits associated with higher highway speeds and reduced aggregate VMT. Benefits would be characterized as the total benefits of travel accruing to the net new highway users instead of the additional benefits accruing to continuing highway users and the external (social) benefits of reduced auto travel. In reality, probably a bit of both would occur — there would be some highway mobility improvements due to the transit mode shift, and some induced highway demand.

While the users' economic value of induced highway trips could, in theory, be estimated (e.g., the value of a newly induced auto trip is greater than or equal to the total time and out-of-pocket costs of the trip), the current state-of-the-practice is to assume that no additional highway trips are generated as the result of a transit investment. In other words, any increase in highway capacity resulting from a mode shift to an improved transit system would NOT be immediately replaced by new auto users. Most studies opt for this simplifying assumption, partly due to constraints in travel demand model output (i.e., most travel demand models are unable to capture induced highway auto trips). There is industry debate regarding the existence of induced highway demand, but most experts agree that vacated highway spaces will be filled by other vehicles in the long term. If it were accepted that induced demand occurs, the available tools for estimating the level of induced travel as well as for estimating the overall combined impact of the two potential reactions (flow improvement and induced trips) have limitations. The PSRC travel demand model is similar to other regional travel demand models in that it cannot directly estimate the level of induced highway demand. Moreover, the benefits of highway flow improvement could ultimately be very similar to the benefits of new trips with no change in flow conditions.

Accordingly, the ST2 B/C analysis proposes to exclude the potential new auto trips and associated benefits induced by vacant spaces on the highway network, and focus on the highway benefits of improved flow for remaining travelers after a transit mode shift, recognizing that the actual combined effect of induced trips and flow benefits, if predictable by the current modeling tools, would likely equal or exceed the predicted mobility benefits arising from improved flow conditions only.

6. Travel Time Savings Considerations and Value of Time Assumptions

General Discussion of Travel Time Savings and Reliability

Travel time savings include walk time, wait time, and in-vehicle travel time savings. Travel time is considered a cost to users, and its value depends on the disutility (cost or disbenefit) that travelers attribute to time spent traveling. A reduction in travel time would translate into more time available for work, leisure, or other activities, which travelers value.

Reliability is an important characteristic of transit service. It has a direct impact on service quality, travelers' perceptions, mode choice, travel time budgets, and user benefits. In essence, reliability refers to the consistency of travel times and wait times. If travel time for a trip is unpredictable, then travelers will need to allow for extra time, effectively making the overall cost of the trip higher.

As a result of having an exclusive right-of-way, the proposed ST2 improvements will enhance travel time reliability for rail travelers who previously traveled either by bus transit or auto. Accordingly, reliability improvements could be realized by ST2 travelers if they make the following mode shifts:

- From Bus to Rail -- The Mid-Ohio Regional Planning Commission (MORPC) travel demand model estimates reliability via an indirect calculation of extra time associated with unreliability through transit wait time curves developed for different modes/service types. In this example, these curves increased transit user benefits by 20-30% on average (PB 2005). Buses are less reliable than rail (unless they use dedicated lanes) because buses operate in traffic. As a result, bus boarding and alighting delays are compounded by traffic congestion, reducing reliability.

- From Auto to Rail -- Though research on the reliability effects of mode shift from auto to rail is sparse, a consensus opinion among travel demand modelers is that auto-to-rail reliability gain is equal to approximately half the bus-to-rail amount (per trip) if the rail operates in a separate right-of-way. In over-congested conditions, auto unreliability would approach bus; in un-congested conditions, there is probably no reliability gain in most cases.

In most travel demand models and corresponding user benefits calculations, reliability is not estimated explicitly; level of service is characterized by average time and cost components. Such approaches, which tend to compensate for missing measures of reliability with artificially inflated constants (often characterized as "rail biases" in mode choice) lead to an underestimation of user benefits.

The ST and PSRC travel demand models — like most of their counterparts — provide only expected value outputs, and are not capable of predicting the additional benefits due to improving

reliability. Accordingly, the ST2 B/C analysis will estimate user benefits conservatively and ignore potential travel time reliability benefits for the ST2 investments.

Value of Time Assumptions

Travel time savings must be converted from hours to dollars in order for benefits to be aggregated and compared against costs in the analysis. This is traditionally performed by assuming that travel time is valued as a percentage of the average wage rate, with different percentages for different trip purposes. For this analysis, assumptions for value of time (VOT) estimates, as percentages of the average wage rate, were derived from a review of other studies.[7] This typically involves valuing travel time for personal travel for a work commute purpose higher than a trip for a non-work or discretionary purpose. However, trip information is not available explicitly by trip purpose in the ST and PSRC models. As such, peak period travel has been adopted as a proxy for the work commute trip purpose, and off-peak travel is assumed to represent non-work/discretionary trip purposes.

The following assumptions are proposed for valuing travel time savings.

- **Peak Period Travel** — Time savings for personal travel (all modes) occurring during the peak period is assumed to be valued at 60% of the average wage rate within the central Puget Sound region (King, Pierce and Snohomish Counties). For auto travel, peak period time savings are assumed to apply to all vehicle occupants.

- **Off-Peak Period Travel** — Time savings for personal travel (all modes) occurring during the off-peak times is assumed to be valued at 50% of the average wage rate within the central Puget Sound Region. For auto travel, off-peak period time savings are assumed to apply only to the vehicle driver.

The average wage rate is estimated using Washington State Employment Security Department (ESD) employment counts and data on wages and salaries paid for 2006, which is the most recent calendar year available. Estimating the wage rates separately for each county, the weighted average is $24.72 per hour for the three-county region. Escalating this figure to 2007 dollars using the Seattle-Tacoma-Bremerton MSA Consumer Price Index, the average hourly wage rate is $25.68 per hour, indicating a peak VOT of $15.41 and an off-peak VOT of $12.84.

Commercial Trip Assumptions

In addition, it is acknowledged that commercial trips tend to have a much higher value of time than personal travel. A reasonable value of time saved for regional commercial travel is approximately 120% of the average hourly wage rate for heavy and tractor trailer truck drivers (US DOT 2003). This value of time for commercial vehicles considers the total compensation of the driver, equal to the driver's wage plus 20% for the fringe benefit costs incurred by the business owner.[8] The cost of the driver's time represents the minimum opportunity cost for the business owner for travel delays in freight movement. The true value of time lost or saved for a commercial trip would be even higher than the driver cost if the cargo were perishable or very high value added commodity. According to ESD data, the hourly wage rate for heavy and tractor trailer truck drivers for the

---

[7] See the citations for Oregon DOT (2004); USDOT, (1997; Revised February 2003); Parsons Brinckerhoff (2004); ECONorthwest and Parsons Brinckerhoff (2002); Litman (2006).

[8] This assumption implies that the typical commercial vehicle driver earns the average wage rate.

Seattle-Bellevue-Everett-Tacoma metropolitan area was $19.38 (in 2006 dollars). Escalating this figure to 2007 dollars using the Seattle-Tacoma-Bremerton MSA Consumer Price Index, the hourly wage rate is $20.13 per hour.

Indirect highway benefits accruing to commercial travel from the ST2 investments will be estimated based upon the simple proportion of total travel represented by commercial vehicles. Using the vehicle proportions in the PSRC model (2030-no action), the share of commercial vehicles relative to the total number of vehicles is 17.4% for off-peak travel and 6.1% for peak period travel.

Value of Time Real Growth Assumption

Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation. Increases in the level of wage and salary incomes per job above and beyond general inflation are referred to as real increases. Between 1970 and 2000, average wage and salary incomes in King County grew at an inflation adjusted average annual real rate of 1.25%, while the State as a whole saw average real growth of 0.73% per year.[9]

Based on the historical trends for real wages, the values of time derived from them are assumed to grow by 1.0% per year from 2007 forward over the project evaluation period.

7. Annualizing Factor Assumptions

Regional travel demand models produce outputs on daily or sub-daily basis. For example, the ST Transit model evaluates travel conditions for a three hour peak period (representative of both a.m. and p.m. peak conditions, for a total of six hours out of the day), and an 18-hour off-peak period. Accordingly, annualizing factors are necessary to convert the travel demand outputs associated with each evaluation period to yearly values. The following annualizing factors (days per year) are assumed:

Peak Period Travel	= 255 [includes five working days per week, 52 weeks per year and 5 holidays per year]
Off Peak Travel	= 400 [includes off peak periods during the 255 work days and converts the 18 hour evaluation period to a 24 hour period for each weekend and holiday]
Peak and Off Peak Parking	= 305 [most parking choices are made on a daily basis. As a result, the Sound Transit model default value of 305 is assumed for this output]

ECONOMIC BENEFITS INCLUDED IN THE EVALUATION

The following identifies and groups the benefits that are proposed for inclusion in the economic evaluation of the ST2 investments.

---

[9] Calculated from wage and salary data obtained from the Washington State Employment Security Department and price level data from the U.S. Bureau of Economic Analysis' Implicit Price Deflator for personal consumption.

1. Transit User Time Savings

Output from the ST travel demand model will be used to estimate transit user time savings, which tend to comprise the majority of benefits accruing to riders. These time savings benefits are based on the consumer surplus theory/concept outlined in the Key Analytical Section. The ST model generates estimates of peak and off-peak transit travel time savings by trip origin-destination pairs at a zonal level (where there are over 750 zones within the ST boundary area). This approach is consistent with the methodology recommended by FTA to calculate user benefits for New Starts transit projects. As such, it provides peak period and off-peak period summaries of travel time savings at a zone-to-zone or district-to-district level for existing riders as well as for new riders (data is generated for existing and new riders, separately).

Benefits associated with transit travel time savings will use the value of time assumptions and growth rates outlined in the Key Analytical Assumptions section. This assumes travel time savings are worth 60 percent of the average wage rate for peak period transit trips and 50 percent of the average wage rate for off-peak period transit trips.

Reliability improvements generate additional benefits for transit users, but they are not included in the ST2 B/C analysis.

2. Mobility Benefits for Non-Transit Users

As previously discussed, non-transit trips also receive travel time savings from the ST2 investments. The travel time savings benefits for peak period auto travelers, off-peak auto travelers, and commercial vehicles are included using the value of time assumptions outlined in the Key Analytical Assumptions section. This assumes travel time savings are worth 60 percent of the average wage rate for all peak period auto trips, 50 percent of the average wage rate for off-peak period (including weekends) auto trips, and 120 percent of the average wage rate for commercial vehicle trips. The values of time would be used in conjunction with the output from the PSRC model (i.e., change in VMT and vehicle delay by time period) to estimate the mobility benefits for non-transit users.

3. Reductions in Vehicle Operating Costs and Auto Ownership Costs

The proposed ST2 investments would not only affect travel times, but they would also reduce vehicle operating and ownership costs for non-transit users. Because some drivers will instead choose to use transit, there will be fewer automobiles on the road, and thus, fewer vehicle miles traveled (VMT). Aside from reducing congestion and increasing vehicle speeds, lower VMT results in quantifiable vehicle operating cost savings. It may also encourage some transit users to own fewer vehicles.

In terms of operating costs, shifting from driving to transit reduces overall vehicle miles traveled, which provides savings in the marginal costs of auto travel (fuel, maintenance and tires). The American Automobile Association estimates the variable, out-of-pocket cost for fuel, maintenance and tires at $0.17 per mile in 2007 dollars.[10]

[10] "Your Driving Costs" (2006); this value are consistent with others reviewed in current literature.

A reduction in VMT due to the ST2 investments also results in less vehicle depreciation (higher vehicle resale value) and reduced vehicle ownership costs for households that shift to transit. Some households will save money associated with vehicle usage, and a small share will save even more by altering their auto purchase decisions (i.e., reducing the number of vehicles owned). Households that have good transit accessibility and own multiple vehicles are strong candidates to reduce their auto ownership level.

The ST2 B/C analysis assumes that 90 percent of the total reduction in VMT is attributable to reductions in vehicle usage, saving some variable costs associated with vehicle ownership (e.g., depreciation and finance charges). The remaining 10 percent of the reduction in VMT is attributable to reductions in auto ownership, which is worth more because it also eliminates fixed costs associated with auto ownership (e.g., insurance, licensing, and registration). Based upon a review of the state of the practice,[11] the analysis proposes to use the values (in 2007 dollars) cited in Exhibit 8 to estimate the benefits of reduced vehicle ownership.[12]

Exhibit 8 — Vehicle Ownership Cost Savings by Vehicle Type

90 % of the reduction in VMT is attributable to reductions in vehicle usage, resulting in a change in SELECTED components of ownership						
	Small Sedan	Medium Sedan	Large Sedan	4WD SUV	Minivan	Average
Depreciation (15,000 miles annually)	$1,300	$1,791	$2,194	$2,210	$2,100	
Finance charge (10% down; loan @ 6% / 5 years)	$265	$384	$467	$486	$431	
Cost per year	$1,565	$2,175	$2,661	$2,695	$2,531	$2,326
Cost per mile	$0.10	$0.15	$0.18	$0.18	$0.17	**$0.16**
10 % of the reduction in VMT is attributable to reductions in vehicle ownership, resulting in a change in the FULL cost of auto ownership						
	Small Sedan	Medium Sedan	Large Sedan	4WD SUV	Minivan	Average
Full-coverage insurance	$927	$937	$1,020	$954	$876	
License, registration, taxes	$412	$572	$684	$710	$636	
Depreciation (15,000 miles annually)	$1,300	$1,791	$2,194	$2,210	$2,100	
Finance charge (10% down; loan @ 6% / 5 years)	$265	$384	$467	$486	$431	
Cost per year	$2,904	$3,685	$4,365	$4,358	$4,043	$3,871
Cost per mile	$0.19	$0.25	$0.29	$0.29	$0.27	**$0.26**

[11] ECONorthwest and Parsons Brinckerhoff (2002); Minnesota Department of Transportation (2003); Wilbur Smith Associates and Urban Systems (2005); AAA (2006); AASHTO 2003; and Litman (2006).
[12] The recommended values were calculated assuming that vehicles drive 15,000 miles per year on average.

Because VMT data disaggregated by vehicle type is not available, the ST2 B/C analysis uses the average cost per mile values to calculate vehicle operating cost and vehicle ownership savings.[13]

In equation form:

Vehicle Operating Cost Savings = (Total VMT savings * 100%) * $ 0.17

Vehicle Ownership Savings = [(Total VMT savings * 90%) * $ 0.16] + [(Total VMT Savings * 10%) * $0.26]

4. Accident Cost Savings

Reductions in VMT lower the incidence of traffic accidents. The cost savings from reducing the number of accidents include direct savings (e.g., reduced personal medical expenses, lost wages, and lower individual insurance premiums) as well as significant avoided costs to society (e.g., second party medical and litigation fees, emergency response costs, incident congestion costs, and litigation costs). The value of all such benefits – both direct and societal – could also be approximated by the cost of service disruptions to other travelers, emergency response costs to the region, medical costs, litigation costs, vehicle damages, and economic productivity loss due to workers inactivity.

The state-of-the-practice in B/C analyses is to estimate accident cost savings for each of three accident types (fatal accidents, injury accidents, or property damage only accidents) using the change in highway VMT.[14] Some studies perform more disaggregate estimates of the accident cost savings, applying different accident rates to different types of roadways (e.g., interstate, highway, arterial).

The ST2 B/C analysis proposes to estimate the benefits associated with accident cost savings using the PSRC model's estimates of the ST2 investments' impact on VMT for (1) combined interstate and state highways and (2) combined county and city arterials. Based on output from the PSCR model, a 50-50 distributional between VMT savings on arterials and VMT savings on highways is assumed. The change in VMT for each of these roadway facility types is then used to calculate the change in the number of fatal accidents, injury accidents, and property damage only accidents (yielding a total of six accident savings figures) using the accident rates shown in Exhibit 9.

Additionally, this analysis assumes the accident disbenefits of the ST2 investments (i.e. some rail track will be at-grade and may be involved in accidents) would be offset by the benefits accrued via reduced bus VMT. As such, accident costs associated with increased rail VMT have been omitted from this analysis.

---

[13] Since an average vehicle lasts longer than 60,000 miles, in accordance with AASHTO recommendations (2003), the vehicle depreciation and finance costs were halved.

[14] Parsons Brinckerhoff (2004); National Safety Council (2004); and Booz-Allen Hamilton in association with Hagler Bailly and Parson Brinckerhoff (1999)

Exhibit 9 — Accident Rate by Facility and Accident Types

Facility Type/Classification	Accident Rates by Type per 100 million VMT		
	Fatality Accidents	Injury Accidents (Non Fatal)	Property Damage Only Accidents
Combined Interstate/State Highways[15]	1.1	53.3	106
Combined County & City Arterials[16]	1.4	113.7	226

The benefits resulting from accident reduction are converted to monetary values using the cost of fatal, injury, and non-injury highway accidents cited by the National Safety Council. On a cost per accident basis, a comprehensive valuation of economic costs of accident avoidance is typically higher than the calculable costs of actual motor-vehicle crashes, the latter being limited to an accounting of wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employer costs.

Exhibit 10 shows comprehensive economic costs for avoiding accidents by accident severity, which reflect the willingness to pay for avoidance (these costs are in 2002 dollars).[17] These economic costs are comparable to the ones used in the California Life-Cycle Benefit-Cost Analysis Model (Cal-BC).[18] Accident benefits are equal to the accident rate multiplied by the value of accident avoidance.

Exhibit 10 — Dollar Values of Accidents by Event

Accident Severity		Historical Calculable Cost	Comprehensive Economic Cost of Avoidance
Fatality Accidents	Death	$ 1,090,000	**$ 3,470,000**
Injury Accidents	Nonfatal Disabling Injury	39,900	**119,650**
	Incapacitating Injury (A)	52,100	172,000
	Non-incapacitating Evident Injury (B)	17,200	44,200
	Possible Injury (C)	9,800	21,000
Property Damage	Property Damage Crash (including non-disabling injuries)	6,200	**8,200**

Source: National Safety Council 2004

In 2007 dollars, fatal accidents are valued at $3,953,124, injury accidents are valued at $136,309, and property-damage only accidents are valued at $9,342.

---

[15] Reflects a VMT weighted average of Interstate and State highways; Source WSDOT, based on average of rates for 1999 through 2002.
[16] Reflects a VMT weighted average of County and City Arterials: Source WSDOT, based on 2002 data only (no data available for 1999 through 2001.
[17] The Nonfatal Disabling Injury is a weighted average of the sub-sections incapacitating Injury, non-incapacitating evident injury, and possible injury.
[18] The assumed values of a fatal accident, injury accident, and property damage only (PDO) accident in Cal-BC are $3,104,738, $81,572, and $6,850, respectively (all values in year 2000 dollars).

5. Parking Cost Savings

Reductions in the number of auto trips caused by the ST2 investments may also reduce expenditures on parking, depending on trip destinations. With additional transit use, short-term parking benefits could be manifested in terms of reduced demand for parking spaces, and hence, potentially lower parking costs. In the long run, reduced land requirements for parking facilities may free up land for other uses.

The ST model produces an estimate of parking cost savings based upon the mode shift to transit for trips to zones with paid parking (e.g., zones within downtown Seattle). The ST2 B/C analysis proposes to use the ST model's estimate of parking cost savings to calculate this benefit.

The ST model estimates parking costs as an avoided cost, which is based on the estimate of new riders and the model's assumption of auto occupancy. In essence, parking costs savings are a byproduct of transit ridership forecasts. The ST model's estimate of new riders is used to calculate parking costs savings.[19]

The ST model's procedure may underestimate long run parking cost savings because not all parking is paid for by the user. The procedure ignores parking savings for employers who provide free parking to their employees. This is often described in two parts: (1) costs of parking included in price of goods and services or an employee benefit; and (2) cost of on street free parking and municipal and institutional off-street parking. According to Delucchi, these costs are about 8 cents/VMT and about 2 cents/VMT, respectively.

6. Energy Conservation and Reduced Air, Noise, and Water Pollution

The ST2 investments can create environmental benefits by reducing air, noise, and water pollution associated with automobile travel. In addition, transit travel is usually more energy efficient than auto travel (in terms of energy consumed per traveler), creating benefits associated with energy conservation. The state-of-the-practice typically expresses the energy and environmental benefits in a cost per VMT basis. Exhibit 11 summarizes the estimated average energy, air, noise, and water pollution costs (in 2003 dollars) of various vehicles.

Exhibit 11 — Average Environmental Costs by Vehicle and Area Type

	Urban	Suburban	**Average**
Current Diesel Buses	30 cents/VMT	15 cents/VMT	22.5 cents/VMT
New Diesel Buses (2004 standards)	15 cents/VMT	5 cents/VMT	10 cents/VMT
Hybrid Electric Buses	5 cents/VMT	3 cents/VMT	4 cents/VMT
Average Car	5 cents/VMT	3 cents/VMT	4 cents/VMT
SUV, Light truck, Van	10 cents/VMT	6 cents/VMT	8 cents/VMT
Average Automobile	7.5 cents/VMT	4.5 cents/VMT	**6 cents/VMT**

Source: Litman, 2006

In 2007 dollars, the average environmental cost is 7 cents/VMT.

[19] Parsons Brinckerhoff (2006)

The ST2 investments can also contribute to reductions in global warming by encouraging travelers to switch from auto to rail. Similar to other environmental benefits, a cost per VMT estimate would need to be established, however, there is not a widely accepted practice for monetizing contributions to global warming. One of the challenges associated with monetizing global warming impacts is assigning a dollar value to what is essentially a non-reversible effect. Because there is sufficient uncertainty and variability in the environmental cost estimates, the B/C analysis does not adjust the figures in Exhibit 11 to account for global warming impacts.

Because disaggregate estimates of the change in VMT for each of the vehicle and area types will not be available, the ST2 B/C analysis uses 7 cents per mile as the average environmental benefit associated with auto VMT reductions. Additionally, this analysis assumes the environmental costs from rail are offset by the environmental savings from reduced bus VMT.

ECONOMIC BENEFITS NOT INCLUDED IN THE EVALUATION

The following is a summary of other potential benefits that will be excluded from the proposed B/C analysis. The ensuing discussion describes these possible benefits and explains the rationale for their exclusion.

1. Reliability

As mentioned previously, the ST2 B/C analysis will estimate transit user benefits conservatively and not include reliability benefits in the quantitative evaluation. In other metropolitan areas that have studied transit reliability extensively, light-rail (LRT) reliability improvements have been estimated to increase transit user benefits by 20-30% on average for riders who previously used bus service. Similarly, LRT reliability gains are estimated to equal half the bus-to-LRT amount (per trip) on average when LRT operates in a separate right-of-way. Commuter rail service would be expected to have reliability advantages over bus service that are similar to LRT. Accordingly, ST2 benefits may be underestimated considerably by excluding reliability improvements from the B/C analysis.

Any potential reliability improvements for non-transit users are also excluded from the B/C analysis.

2. Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of Transit Operating and Maintenance Expenditures

Transit operations are traditionally labor intensive and transit expenditures tend to provide more jobs and local economic activity than most other transportation investments. For example, one study estimated that each million dollars of transit capital investment generated between 30 and 60 additional jobs.[20] Despite the significant direct and multiplier effects of the investment on the local economy, it is unlikely that these impacts would represent net benefits to the region unless operations and maintenance (O&M) expenditures were financed from federal dollars that otherwise would not have been distributed to the region. If locally funded O&M expenditures were not used by Sound Transit, these same dollars would be put to some other productive economic use within the region, which would also generate economic activity, jobs, and employment earnings (albeit at a

[20] ECONorthwest and Parson Brinckerhoff (2002).

potentially lower multiplier). Therefore, the employment, income, and output effects of transit O&M expenditures are excluded from the ST2 B/C analysis.

3. Direct, Indirect and Induced Impacts on Employment, Earnings, and Output of Transit Construction Expenditures

Similar to operations and maintenance expenditures, construction expenditures also generate additional economic activity, jobs, and employment earnings. This construction impact has three components: (1) direct impacts from expenditures on construction materials, service and labor; (2) indirect impacts from subsequent intra- and inter-industry purchases of inputs and production of outputs as a result of the initial direct expenditures/change in output of the directly affected industry; and (3) induced impacts generated from increases in household spending on goods and services that result from additional employment earnings through the direct and indirect effects.

Multipliers derived from an input-output model are usually used to estimate the total impact on output, employment, and earnings from the direct construction expenditures. Output, employment, and income multipliers represent a quantitative expression of the extent to which the construction of a transit project may generate additional economic activity and employment through interdependencies associated with some assumed and/or empirically established, "endogenous" inter-industry linkage system. While these levels of employment and income are tangible and clearly beneficial to many individual economic sectors (particularly the construction industry), the validity of including such benefits in a formal B/C analysis has been questioned by a number of economic analysts, on the premise that construction spending represents a transfer of income from taxpayers to the transit agency, or from other public investment purposes. Put another way, like in the above O&M case, the money would be spent by consumers and/or the public sector on other things, generating similar multiplier effect on the local economy, albeit with a different distribution.

A case could be made for considering the portion of construction supported by federal grant dollars under the presumption that without the project, the region or state would not receive this funding. Similarly, a case could also be made for considering additional future federal funds that the project will generate for the region because it increases the region's fixed-guideway miles, which are used in a formula to calculate region's share of (federal) Section 5309 fixed-guideway modernization funds. However, multiplier benefits will be excluded from the B/C analysis because discretionary federal funds have not been identified for the ST2 investments.

If the ST2 financial plan were to adopt an assumption for federal grant funding, then this exogenous funding could be treated in one of two ways. The direct and multiplied impacts noted above could be considered as project benefits during the construction period, but such an approach is not widely practiced. Alternatively, the federal share of the overall project cost could be deducted (excluded) from the B/C analysis since these costs would not be locally borne within the defined study region. This is the recommended approach for dealing with federal grant funding, such as FTA New Starts funding.

4. Increased Property Values near Stations

Bay Area Economics (2005), among others, have estimated a statistically significant positive association between proximity to light rail stations and property values - i.e. development located closer to transit stations is likely to have higher property values than development located farther

from stations. Exhibit 12 shows select studies of property value impacts for different U.S. rail systems.

Exhibit 12 — Station Area Property Value Impacts from Select Studies

System	Impact	Study
Boston MBTA	6.7% premium for single family residences located in communities near commuter rail stations	Armstrong (1994)
Los Angeles MTA	After announcement of new transit stations, commercial property values in expected station areas grew 78% compared to 38% for properties not located in expected station areas	Fejarang (1994)
Philadelphia PATCO	10% premium for median home prices in census tracts served by rail line	Voith (1991)
Philadelphia SEPTA	3.8% premium for median home prices in census tracts served by rail line	Voith (1991)
San Francisco BART	10% - 15% increase in rent for rental units within 1/4 mile of BART	Cervero (1996)
Washington, DC Metro	10% decrease in distance to a station results in a 1.3% change in single family home property value and a 6.8% change in retail property value	Lerman et al. (1978)
Washington, DC Metro	A 1,000 ft decrease in walking distance to Metrorail stations increases commercial property values by $2.30 per square foot; worth about $70,000 for the average commercial property	FTA (2000)

Despite the evidence of increased property values near stations, it is reasonable to exclude these effects because property value increases may be viewed as a market response to reduced transportation costs, among other factors, in which travel time benefits are capitalized into the value of adjacent property. As a result, including property value increases would comprise at least some degree of benefit double counting.

5. Barrier Effect

"Barrier effect" benefits include reducing the delays and discomfort imposed on non-motorized modes (pedestrians and cyclists) by vehicle traffic. For example, it's more stressful for pedestrians to cross a busy street than to cross a quiet street with few vehicles, and this stress has a societal cost. Because the ST2 investments are expected to reduce auto VMT, the barrier effect could also decrease. In addition to direct costs imposed on pedestrians, bicyclists, and residents, the barrier effect can include costs associated with automobile dependency and chauffeuring.

Barrier effects could be monetized by multiplying the costs in Exhibit 13 by the estimated VMT savings for each vehicle type. The cost estimates in Exhibit 13 are in 1996 dollars.[21]

[21] Rural values have been omitted from the table.

Exhibit 13 — Barrier Effect Costs per VMT by Vehicle Type and Time of Day

	Urban Peak	Urban Off-Peak	**Average**
Compact Car	1.5 cents/VMT	1.0 cents/VMT	0.9 cents/VMT
Electric Car	1.5 cents/VMT	1.0 cents/VMT	0.9 cents/VMT
Van/Light Truck	1.5 cents/VMT	1.0 cents/VMT	0.9 cents/VMT
Diesel Bus	3.8 cents/VMT	2.5 cents/VMT	2.3 cents/VMT
Average Car	1.5 cents/VMT	1.0 cents/VMT	**0.9 cents/VMT**

Source: Victoria Transport Policy Institute 2005 (amounts expressed in 1996 dollars)

Unlike congestion costs, where each additional vehicle can have a large effect on the amount of overall vehicle delay, the marginal barrier effect of an additional vehicle is quite small. Moreover, the barrier effect could actually increase on some facilities if the ST2 investments increase auto speeds. As a result, this benefit stream appears negligible, and it is omitted from the proposed analysis.

6. Transit Fares

Transit fares are an economic transfer from users to the transit agency. Because they are a pecuniary transfer, they represent neither an economic benefit nor an economic cost of the project. In the proposed analysis, transit fares are excluded from both the benefit and O&M cost tabulations.

7. Induced Transit Travel

Additional transit travel can be disaggregated into two types – 'redistributive' and 'generative'.[22] For the ST2 investments, the majority of the redistributive travel is captured via the outputs generated by the ST and PSRC travel demand models - i.e. additional transit travel that occurs as a result of less auto travel caused by the mode shift.

The generative, or 'induced', effects are harder to capture than the redistributive effects. Because the ST2 investments lower the generalized cost of travel, they will likely induce additional travel (i.e., create trips that simply were not made prior to the transit improvements). Although travel demand modeling capabilities prohibit formal inclusion of ST2 induced transit travel in the quantified evaluation, benefits associated with additional travel are expected.[23]

8. Unpriced Parking

As mentioned previously, the ST model only estimates parking benefits for parking that is paid for by users. If the ST2 investments reduce the number of parking spaces an employer provides to its employees at no cost, these benefits will not be included in the ST model estimate of parking savings. Because the ST2 investments will cause some people to ride transit instead of drive—

---

[22] Cervero (2001).

[23] The proposed descriptive analysis would make use of several ex-post rider-ship surveys (from the CTA Orange Line and North Central Lines), which indicate that a good number of riders using these new services are travelers who simply did not make the trip prior to the introduction of the new service, either by taxi, auto, or other transit service. Presumably these are discretionary trips, trips that were too costly or inconvenient by any mode previously, or trips by individuals who had few, if any, other travel options before.

reducing the need for free as well as for-payment parking spaces—the parking benefits included in the ST2 B/C analysis are likely to be underestimated.

ECONOMIC COSTS AND ASSUMPTIONS INCLUDED IN THE EVALUATION

In the proposed benefit-cost analysis, the term 'cost' refers to the additional resource costs or expenditures required to implement, perpetuate, and maintain the investments associated with the ST2 improvements.

The proposed B/C analysis will use project costs that have been estimated for the ST2 program on an annual basis, expressed in 2007 dollars. Environmental, design and other pre-construction costs which may occur prior to 2012 are assumed to occur uniformly between 2012 and 2015, consistent with the project evaluation period assumptions in Exhibit 5. These cost estimates,[24] which are described below, will be provided by Sound Transit.

Initial Project Investment Costs

Initial project investment costs include engineering and design, construction, acquisition of right-of-way, vehicles, other capital investments, and contingency factors. The project capital investment costs are typically treated in one of two basic ways. The first, and most common, is to treat the project costs as up-front costs coinciding with the actual project expenditures on a pay-as-you go basis. This approach will exclude financing costs from long-term borrowing as part of the investment expenditures subject to present value calculations.

An alternative approach would consider the proposed financial plan for the investments, when the plan involves long-term debt that is repaid over time with interest, and account for the financing costs as the debt is repaid. The two approaches yield essentially the same results for the discounted present value of the project investment costs.[25] As a result, the former pay-as-you-go assumption is usually adopted in recognition that a detailed financial plan typically would not yet be available at the time when B/C analysis of project alternatives is undertaken.

To understand why debt service costs over time for financed investments equate to the same present value as up-front, pay-as-you-go investments, note that debt service amounts are expressed in nominal dollars, calculated using a nominal interest rate that includes both real and inflationary components. Because B/C analysis typically accounts all dollar amounts in constant dollars of a single year (e.g., 2007 dollars), it is necessary to convert the stream of debt service payments into constant dollars. However, once inflation is extracted from the nominal debt service payments, the remaining debt service is simply a stream of principal repayments and real interest payments.[26]

[24] The proposed analysis does not depreciate costs, since it represents a sinking fund for future replacement of an asset. If the analysis were to depreciate costs, a similar process would also have to be done on the benefit side, thereby balancing each other out.
[25] A small difference may result from financing costs such as the underwriter's fees which would not be part of pay-as-you-go investment.
[26] Assuming the project can secure debt with a solid credit rating such that there is no material risk component also factored into the borrowing interest rate. An interest rate premium for risk could result in a higher net present value

Converting this stream of real debt service payments to its present value using a real discount rate cancels out the real interest paid over time, leaving the sum of the principal payments — the original level of investment. Put another way, the long term real cost of capital for public transit investments in a relatively risk free environment is essentially equal to the real discount rate.

Annual Operating and Maintenance Costs

The annual cost of operating and maintaining the proposed rail investments is included in the analysis. Operations and maintenance activities apply to several assets, including rolling stock, stations, track, and support facilities. Additional incremental agency expenses are also included. The costs include regular and ramp-up O&M expenses beginning in 2013 and continuing through the end of the evaluation period. The ramp-up O&M costs incurred prior to 2019 are for additional commuter rail operations during this timeframe. Benefits solely due to this commuter rail service were not estimated and thus, the benefit-cost analysis conservatively omits all benefits associated with the pre-2019 operations.

As previously presented, ridership and transit benefits are projected to exhibit real growth of 1.3% per year after 2030 through 2060. Similarly, O&M costs are assumed to keep pace with inflation up through 2029 (no real growth); experience a one-time real increase of 3.5% in 2030 in addition to normal inflation; and thereafter exhibit real growth (in excess of normal inflation) of 1.3% per year, thereby keeping pace with ridership growth beyond 2030.

Periodic Capital Equipment Replacement Costs and Major Rehabilitation

Several types of initial asset investments will need to be replaced or rehabilitated during the evaluation period. To account for this, the analysis proposes to include rehabilitation/replacement schedules associated with regular asset life cycles and the costs of rehabilitation/replacement. The analysis makes the following assumptions regarding asset life cycles and the rehabilitation/replacement costs:

- 30% of initial construction expenditures are replaced every 80 years (no rehabilitation required during the ST2 evaluation period);
- 70% of initial construction expenditures are replaced every 30 years at cost of no less than 50% of the initial expense, adding 30 years of life; and
- Rail vehicles are replaced every 30 years at a cost of 100% of the initial expense.

Residual Value (Cost Offset or Negative Cost)

Because there is still an economic value to the ST2 investments at the end of the B/C evaluation period (the system will continue operating beyond 2060 and the system will not need to be completely replaced at that time), there is a residual value for some investments such as track infrastructure and right-of-way. The proposed B/C analysis will include residual values as cost savings (i.e., negative cost) in the final year of the evaluation.

Because it does not depreciate (some might argue that it, in fact, appreciates), a residual right-of-way value equal to 100% of the initial right-of-way cost is included in the final year of the evaluation.

---

cost for the project under debt financing than pay-as-you go. However, the use of tax-exempt debt with lower nominal interest rates than taxable debt may offset the real increase attributable to credit risk.

Construction expenditures and rail vehicles are also assumed to have residual values at the end of the evaluation period. It is assumed that these assets depreciate on a straight-line basis. For example, an asset with an 80-year life-cycle is assumed to be worth 50% of the initial investment cost after 40 years.

For simplicity, it is assumed that all life-cycles begin in the first year of full operations, 2021. To illustrate, rail vehicles are assumed to be replaced (at 100% of their initial cost) in 2050, and if the evaluation period ends in 2060, the residual value is 2/3 of the initial rail vehicle cost.

ECONOMIC COSTS NOT INCLUDED IN THE EVALUATION

Federal Funds (Cost Offset or Negative Cost)

New federal funding brought to the region as a result of the ST2 investments will not be included in the analysis. Because the study region is defined to be the three-county ST service district, additional federal funds would be a negative (offsetting) cost of the project. Some might think of this as project benefit, but it is more appropriately classified as a cost reduction for the region. Discretionary federal funds, such as Section 5309 "New Starts" funds allocated by the Federal Transit Administration (FTA), would be new federal funding for the region. Similarly, the ST2 investments should increase the region's allocation of FTA Section 5309 Fixed-Guideway Modernization formula funding, which would also reduce the region's cost of the ST2 investments.

The ST2 B/C analysis will conservatively ignore any potential new federal funding brought to the region by the ST2 investments.

KEY BENEFIT-COST EVALUATION MEASURES

There are three common benefit-cost evaluation measures, each tailored to compare benefits and costs from different perspectives.

Net Present Value

The benefit-cost analysis will convert potential gains and losses from the proposed investment into monetary units and compare them on the basis of economic efficiency, i.e., net present value (NPV). For example, NPV = PVB (present value of benefits) - PVC (present value of costs); where:

$$PVB = \sum_{t=0}^{T} B_t / (1+ r)^t; \text{ and } PVC = \sum_{t=0}^{T} C_t / (1 + r)^t$$

and the NPV of a project can be represented as:

$$NPV = \sum_{t=0}^{T} (B_t - C_t)/ (1+r)^t,$$

where B_t and C_t are the benefits and costs, respectively, of a project in year t; r is the real discount rate; and T is the time horizon (evaluation period). In essence, NPV gives the magnitude of the project's economic feasibility in terms of net benefits (benefits minus costs) discounted to present values using the real discount rate assumption. Under this criterion, a scenario with an NPV greater

than zero may be considered "economically feasible". The NPV provides some perspective on the overall dollar magnitude of benefits not reflected by the other two measures.

Economic Rate of Return

The Economic Rate of Return (ERR) is the discount rate that makes the present value of all benefits just equal to the present value of all costs, i.e., the real discount rate at which the project's NPV is zero and it's benefit-cost is unity. The ERR measures the social or economic return on investment. As an evaluation measure, it allows comparison of the proposed investment package with other similar packages and/or alternative uses of investment funds that may have different costs, different benefit flows, and/or different timing. Note that the ERR is interpreted as a real rate of return (after accounting for inflation), since the assumption is that benefits and costs are expressed in constant dollars. As such, it should not be directly compared with investment returns calculated from inflated or nominal future year dollars. In some cases, a threshold value for the ERR may be established where exceeding that threshold results in the determination of an economically justified project.

Benefit/Cost Ratio

The evaluation proposes to estimate the benefit-cost ratio; where the present value of incremental benefits divided by the present value of incremental costs yields the benefit-cost ratio (B/C Ratio), i.e., B/C Ratio = PVB / PVC. In essence, the B/C Ratio expresses the relation of discounted benefits to discounted costs as a measure of the extent by which a project's benefits either exceed or fall short of their associated costs. For example, a B/C ratio of 1.5 indicates that the project generates $1.5 of benefits per $1 of cost. As such, a ratio greater than 1 is necessary for the project to be economically worthwhile (feasible). The B/C Ratio can be useful when the objective is to prioritize or rank projects or portfolios of projects with the intent to decide how to best allocate an established capital budget.

Sensitivity Analysis

To test the robustness of the estimated NPV, ERR, and B/C Ratio, the proposed economic analysis will also conduct several sensitivity analyses; where the estimated measures will be re-calculated under varying scenarios (i.e. assumptions). These scenarios will include:

Scenario 1: 15% increase in all calculated benefits
Scenario 2: 15% decrease in all calculated benefits
Scenario 3: 10-year increase in the evaluation period (from 40 to 50 years of full operations)
Scenario 4: No real wage growth in value of time calculation
Scenario 5: 15% increase in initial capital costs
Scenario 6: 15% decrease in initial capital costs

In the scenario where the evaluation period is increased to 50 years, it is assumed that all growth rates are also extended, i.e., continue to grow at the same rate during the additional evaluation years.

Summary Output Format

Exhibit 14 illustrates the summary output of the proposed ST2 B/C analysis.

Exhibit 14 — Key Measures Summary Table Format

Scenario	Net Present Value (NPV)*	Economic Rate of Return (ERR)	Benefit-Cost Ratio (B/C)*
Base Case			
Sensitivity Tests			
Scenario 1: 15% Increase in Benefits			
Scenario 2: 15% Decrease in Benefits			
Scenario 3: 10-Year Increase in Evaluation Period			
Scenario 4: No Real Wage Growth			
Scenario 5: 15% Increase in Capital Costs			
Scenario 6: 15% Decrease in Capital Costs			

SUMMARY

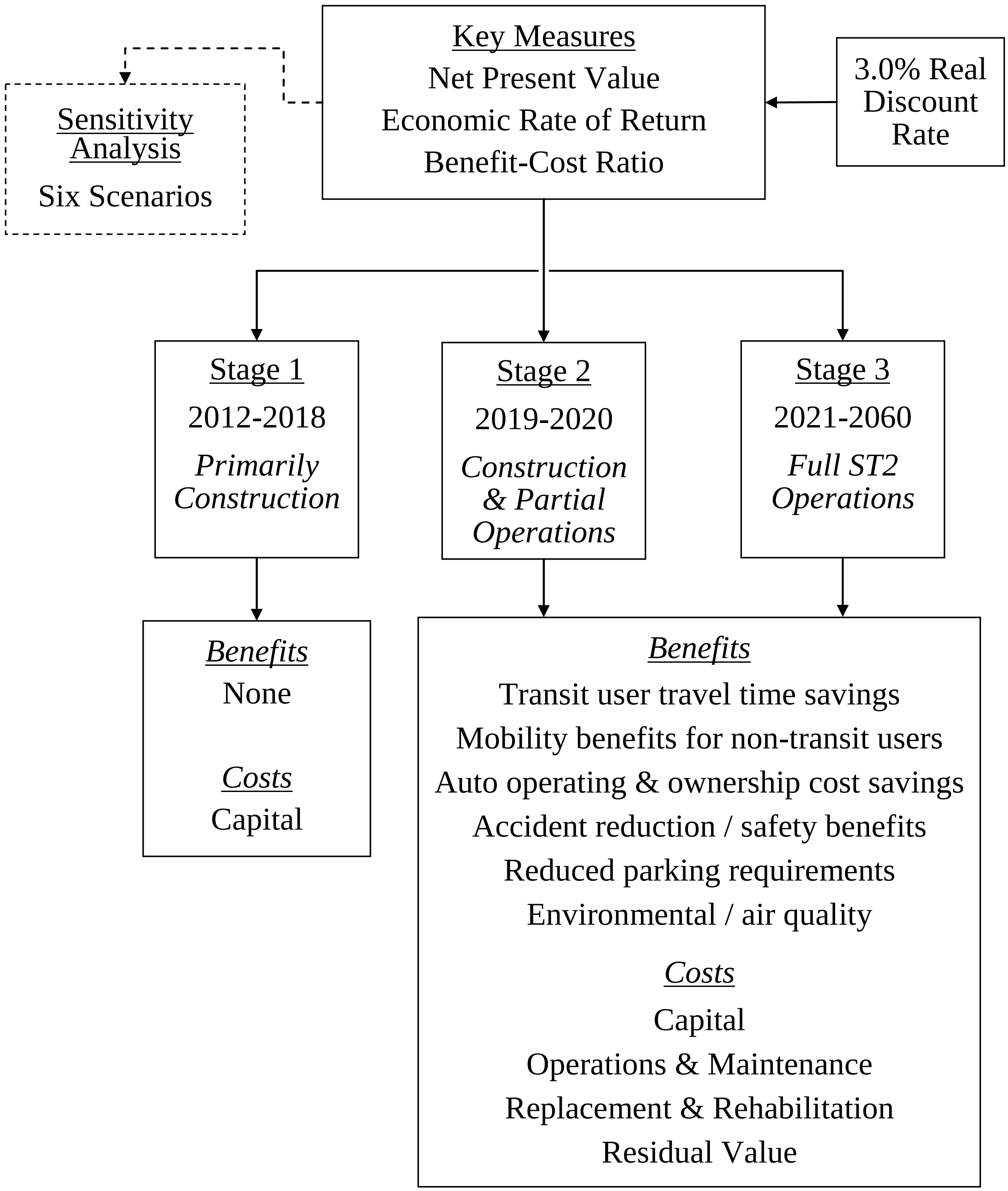
The key benefit-cost analysis assumptions are summarized in Exhibit 15.

Exhibit 15 — Key Assumptions

Unit of Expression	2007 dollars
Inflation Index (Where Necessary)	BLS CPI-U for the Seattle-Tacoma-Bremerton MSA
Real Discount Rate	3.0%
Evaluation Period Primarily Construction Partial Operations (Partial Benefits) Full Operations (Full Benefits)	 2012-2018 2019-2020 2021-2060
Study Region	King, Pierce, and Snohomish Counties
Benefits Growth Rate	Linear via forecasts (2019-30); 1.3% per year (2031-60)
Real Wage Growth Rate	1.0% per year
Real O&M Cost Growth Rate	3.5% increase in 2030; 1.3% per year after 2030
Induced Highway Travel	None
Benefits	
Transit Travel Time Savings	Consumer surplus calculation from ST model outputs
Peak (Commute) Trips	Value of time = 60% of average wage rate
Off-Peak Auto (Non-Commute) Trips	Value of time = 50% of average wage rate
Commercial Trips	Value of time = 120% of average wage rate for tractor and truck drivers
Vehicle Operating/Ownership Cost Savings	17 cents/mile (operating) & 16 - 26 cents/mile (ownership)
Accident Rates	1.1 - 226 per 100 million VMT
Accident Costs Fatal Injury Property Damage Only	 $3,953,124 / accident $136,309 / accident $9,342 / accident
Parking Cost Savings	Estimated by ST model
Environmental Cost Savings	7 cents per VMT
Reliability	Excluded
Direct, Indirect, & Induced Effects from Construction + O&M Expenditures	Excluded
Increased Property Values	Excluded
Barrier Effect	Excluded
Transit Fares	Transfer payment captured in O&M costs
Induced Transit Travel	Excluded
Unpriced Parking	Excluded
Costs	
Initial Project Investment Residual Value Periodic Replacement & Rehabilitation Regular Operating & Maintenance	Estimates provided by ST
Federal Funds	Excluded

Exhibit 16 summarizes the proposed ST2 B/C evaluation process.

Exhibit 16 — Sound Transit Phase 2: Benefit-Cost Analysis Summary Graphic



APPENDIX A — BIBLIOGRAPHY

AASHTO, 1977, "A Manual on User Benefit Analysis of Highway and Bus Transit Improvements"

AASHTO, 2003, "A Manual of User Benefit Analysis for Highways, 2nd Edition"

American Automobile Association, 2006, "Your Driving Costs"

Armstrong, Robert, 1994, "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values," Transportation Research Board, 73rd Annual Meeting

Bay Area Economics, 2005, "Sacramento RT Economic Impacts of Light Rail" presentation made at Rail-Volution Conference in Utah

Bloomberg, 2008, Bloomberg.com

Booz-Allen Hamilton in association with Hagler Bailly and Parson Brinckerhoff, 1999, "California Life-Cycle Benefit-Cost Analysis Model"

Brownstone, David and Kenneth Small, 2003, "Valuing time and Reliability: Assessing the Evidence from Road Pricing Demonstrations", University of California at Irvine

Caltrans, 2004, "Methodology for Discounting Benefits and Costs for Transport Projects in California"

Cambridge Systematics, Robert Cervero, and David Aschauer, 1998, "TCRP Report 35: Economic Impact Analysis of Transit Investments-Guidebook for Practitioners"

Cervero, Robert, 1996, "Transit-Based Housing in the San Francisco Bay Area: Market Profiles and Rent Premiums," Transportation Quarterly, Vol. 50, No. 3, pp. 33 – 47

Cervero, Robert, 2001, "Road Expansion, Urban Development, and Induced Travel: A Path Analysis"

Delucchi, Mark A., October 1996, "The Annualized Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory, Data, Methods, and Results"; Institute of Transportation Studies: UCD-ITS-RR-96-3(1).

ECONorthwest and Parsons Brinckerhoff, 2002, "TCRP Report 78: Estimating the benefits and costs of public transit projects: a guidebook for practitioners"

Federal Transit Administration (FTA), 2000, "Transit Benefits 2000 Working Papers: A Public Choice Policy Analysis," Washington, D.C.

Fejarang, Robert, 1994, "Impact on Property Values: A Study of the Los Angeles Metro Rail," Transportation Research Board, 73rd Annual Meeting, Washington, D. C.

HDR/HLB Decision Economics Inc., 2006, "Socioeconomic Benefits in Transit in Wisconsin"

Lerman, S., D. Damm, E. Lam-Lerner, and J. Young, 1978, "The effects of the Washington Metro on urban property values," MIT Press, Cambridge, MA

Litman, Todd, 2006, "Evaluating Public Transit Benefits and Costs: Best Practices Guidebook"

Minnesota Department of Transportation, 2003, "Per Mile Costs of Operating Automobiles and Trucks"

National Safety Council, 2004, "Estimating the Costs of Unintentional Injuries," http://www.nsc.org/lrs/statinfo/estcost.htm#COST

Parsons Brinckerhoff, 2003, "Northwest Corridor BRT Benefit-Cost Analysis"

Parsons Brinckerhoff, 2004, "Congestion Relief Analysis Project: Benefit-Cost Methodology Technical Memorandum"

Parsons Brinckerhoff, 2006, "Sound Transit Long Range Plan ST2 Planning: Transit Ridership Forecasting Technical Report, prepared for Sound Transit by Parsons Brinckerhoff"

Office of Management and Budget (White House), revised 2006, "Circular No. 94 (appendix C): Discount rates for cost-effectiveness, lease purchase, and related analyses"

Oregon DOT, 2004, "The value of travel time: estimates of the hourly value of time for vehicles in Oregon"

USDOT, April 9, 1997; Revised February 2003, "Departmental Guidance on the Evaluation of Travel Time in Economic Analysis Memo;" used in STEAM software

US DOT, 2003, "Revised Departmental Guidelines: Valuation of Travel Time in Economic Analysis" memorandum

Victoria Transport Policy institute, 2005, "Transportation Cost Benefit Analysis" http://www.vtpi.org

Voith, Richard, 1991, "Transportation, Sorting and House Values," AREUEA Journal, Vol. 117, No. 19

Washington State Employment Security Department, "Workforce Explorer Labor Market Data" website, http://www.workforceexplorer.com (accessed May 5, 2008).

Wilbur Smith Associates and Urban Systems, 2005, "West Kootenay – Northeast Washington Joint Highway Corridor Study"

APPENDIX B — ST2 BENEFIT-COST ANALYSIS RESULTS

Results in Brief

A benefit-cost analysis was conducted for the rail components of Sound Transit's Phase 2 (ST2) plan of June 2008. This analysis was completed and submitted to the Puget Sound Regional Council as part of their conformity review of the ST2 plan. The analysis was conducted in accordance with the methodology described in the *Sound Transit 2 Benefit-Cost Analysis Methodology Report*, to which these results are appended. For the ST2 plan "base case" scenario, the proposed rail investments yield a net present value of $7.0 billion, which provides a real economic rate of return of 7.7%. The associated benefit-cost ratio is 2.3. Exhibit B-1 presents the evaluation results for the base case and six sensitivity tests.

Exhibit B-1 — Benefit-Cost Analysis Summary Results

Scenario	Net Present Value (NPV)*	Economic Rate of Return (ERR)	Benefit-Cost Ratio (B/C)*
Base Case	**$7.0 B**	**7.7%**	**2.3**
Sensitivity Tests			
Scenario 1: 15% Increase in Benefits	$8.9 B	8.6%	2.6
Scenario 2: 15% Decrease in Benefits	$5.2 B	6.7%	2.0
Scenario 3: 10-Year Increase in Evaluation Period	$8.9 B	7.9%	2.5
Scenario 4: No Real Wage Growth	$4.6 B	6.5%	1.8
Scenario 5: 15% Increase in Capital Costs	$6.4 B	6.9%	2.0
Scenario 6: 15% Decrease in Capital Costs	$7.7 B	8.7%	2.6

** Assumes a 3% real discount rate*

All benefits and costs were estimated in constant 2007 dollars over an evaluation period extending 40 years beyond system completion in 2020, with future amounts discounted to their present values using a real discount rate of 3.0%.

Travel Impacts

The ST2 benefit-cost analysis results are based on transit ridership forecasts prepared by Sound Transit using methods reviewed and approved by the Federal Transit Administration and the State Expert Review Panel., and road network travel impacts from the Puget Sound Regional Council (PSRC) model.

Exhibit B-2 on the next page summarizes the key travel impacts of the ST2 rail investments as annual amounts projected for the year 2030.

The ST2 rail investments are predicted to save existing and new transit riders nearly 11 million hours of time per year. New transit riders that shift from their cars to rail will also benefit from savings in vehicle operating costs and parking charges in addition to time savings.

Exhibit B-2 — Travel Impacts Resulting from Rail Investments

ST2 Travel Impact	Annual Value & Units
New Transit Riders	12 million riders
Transit Rider Travel Time Savings (Existing & New Riders)	11 million hours
Vehicle Miles of Travel Saved due to New Transit Riders	180 million VMT
Paid Parking Saved for New Transit Riders	6 million transactions
Traffic Congestion Delay Reduction	13 million vehicle hours

The Sound Transit and PSRC travel demand models estimate that the ST2 rail investments would encourage some auto travelers, especially those making relatively longer trips, to switch to transit. The models predict that the 12 million new riders or transit trips in 2030 would reduce, by 180 million, the annual number of vehicle miles traveled (VMT) on the central Puget Sound region road network. This reduction in VMT is expected to lower traffic congestion and improve mobility over what would have otherwise been the case. The roadway network in 2030 is predicted to be sufficiently congested by 2030 that the impact of the rail investments will yield significant mobility benefits, resulting in 13 million vehicle-hours of time savings from reduced vehicle delay per year.

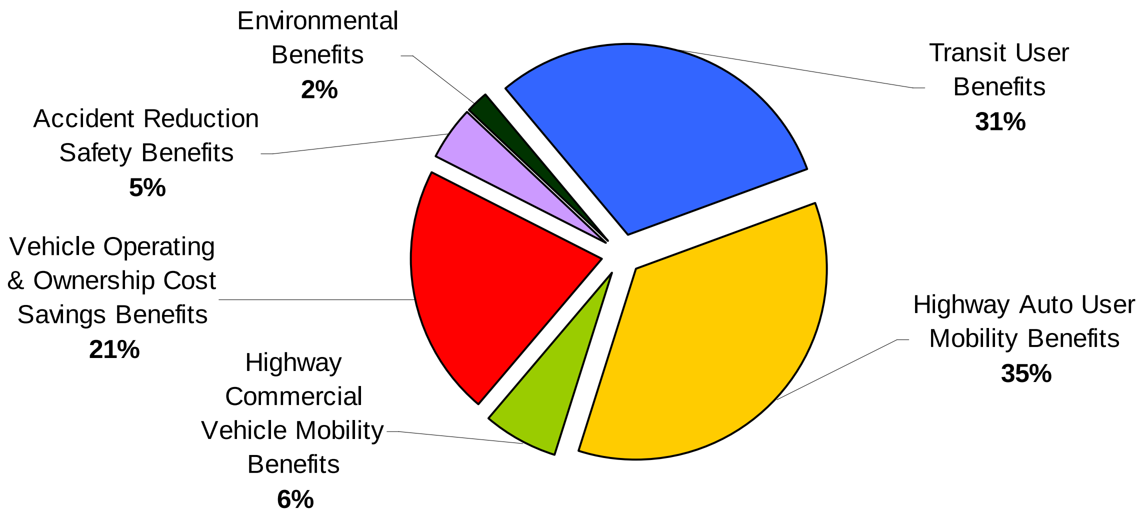
Many people assume that every new transit rider leaving their vehicle behind simply allows another auto trip to occur, resulting in no net change in the level of auto travel or congestion delay. This alternative effect is sometimes referred to as "induced demand." The ST and PSRC models, like most other regional travel demand models, follow the state of the practice by predicting reduced auto travel from new transit investments, and are not equipped to capture this potential induced demand. The assumption of induced auto travel would mean that more trips occur in the entire transportation system than without induced auto travel. This too is a benefit, because all travel — including the induced auto trips — have very real economic value. At a minimum, the value of induced auto travel must exceed its total time and dollar costs, and this value is likely comparable to the congestion relief, safety and environmental benefits that would occur in the absence of induced auto travel.

Empirical evidence suggests that attracting some auto users to transit would actually cause some combination of both highway network mobility improvements and induced highway travel. Additional information on travel demand impacts can be found in the main body of the *Sound Transit 2 Benefit-Cost Analysis Methodology Report.*

ST2 Benefits by Category

The (discounted) present values of all benefits generated over the ST2 evaluation period, expressed in 2007 dollars, are shown in Exhibit B-3, distributed by category.

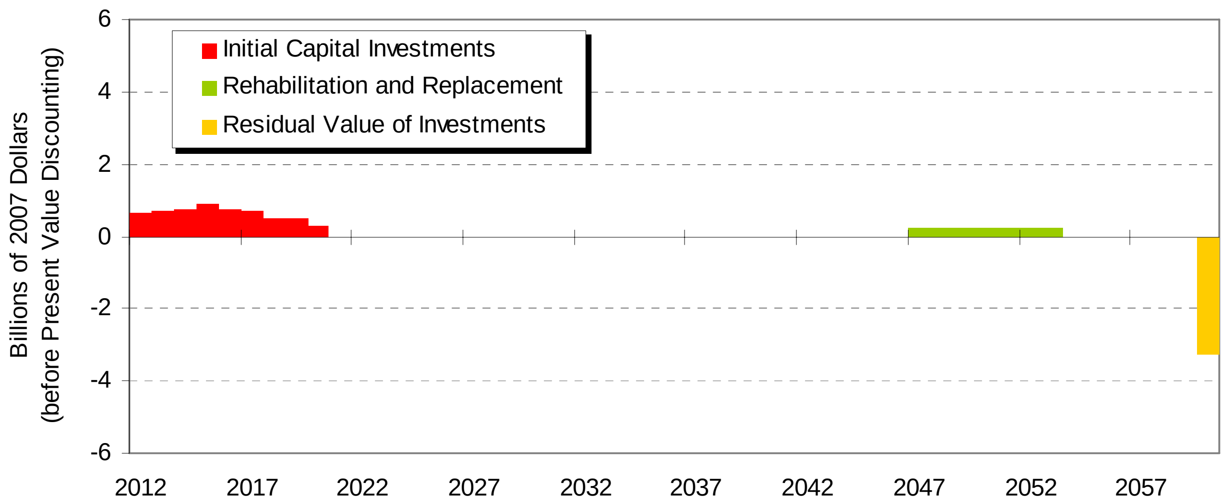
Exhibit B-3 — Cumulative Present Value of Benefits by Category



ST2 Costs over Time

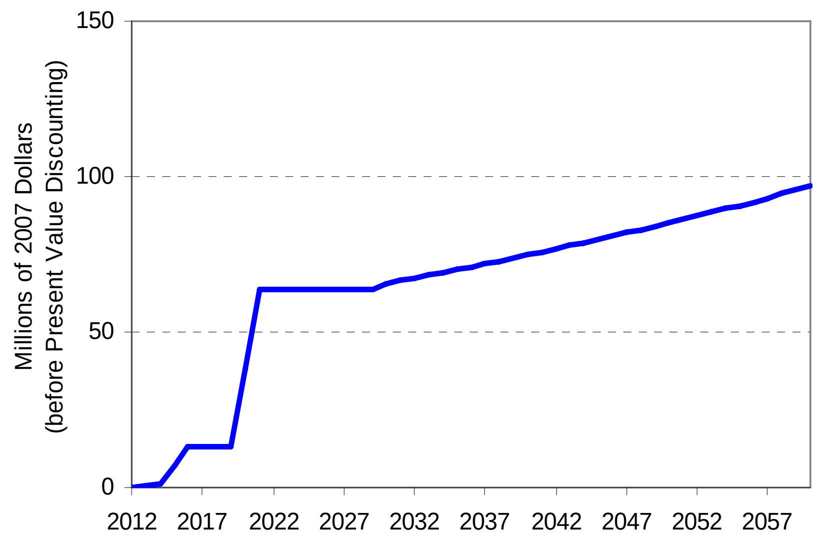
Exhibit B-4 presents the rail capital expenditures over time, expressed in constant 2007 dollars before present value discounting. The initial capital investments ($5.7 billion) were assumed to begin in 2012 and conclude by the end of 2020. The benefit-cost analysis assumed that the rail vehicles as well as 70% of the initial project capital investment (excluding right-of-way) would need to be replaced or receive major rehabilitation, on average, 30 years after full project operations begin. The negative cost or cost credit spike shown in 2060 represents the residual value of the depreciated investments at the end of the economic evaluation period. This nearly $3.3 billion residual value at the end of 2060 is less than $700 million in present value.

Exhibit B-4 — Capital Expenditures in 2007 Dollars before Present Value Discounting



Annual operating and maintenance (O&M) costs over the economic evaluation period are presented in Exhibit B-5, expressed in constant 2007 dollars before present value discounting. The upward sloping line illustrates the assumption of 1.3% real growth in O&M expenditures. This assumption reflects both real growth in O&M cost factors (labor and material costs escalating faster than overall inflation) and expected growth in O&M expenditures to keep pace with increasing ridership over time.

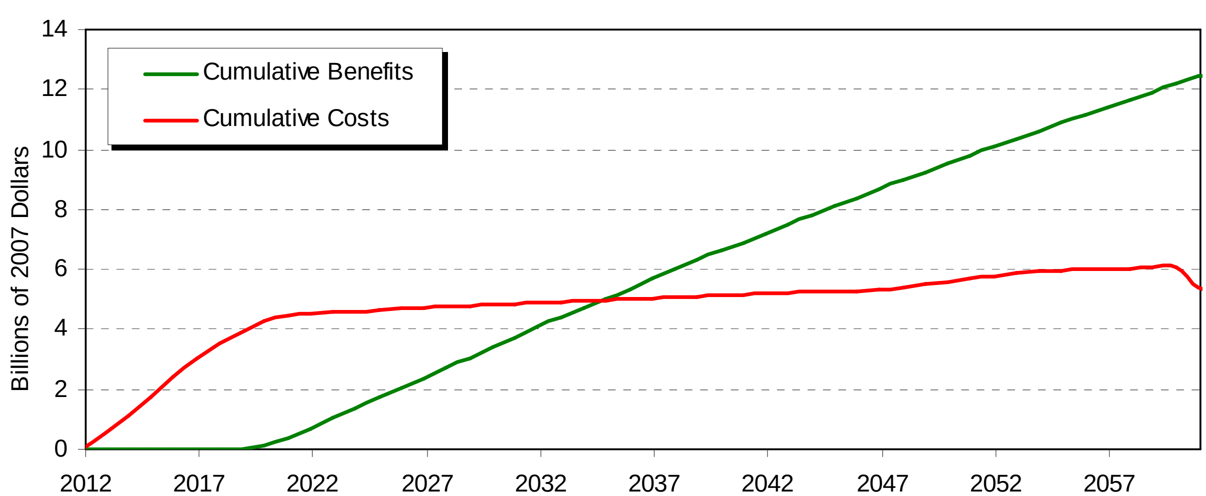
Exhibit B-5 — Annual O&M Costs in 2007 Dollars before Present Value Discounting



Cumulative Benefits and Costs

Exhibit B-6 compares the cumulative present value of benefits with the cumulative present value of costs over time for the base case scenario in Exhibit B-1. The figure shows that the cumulative discounted benefits exceed the cumulative discounted costs by the mid-2030s, or approximately fifteen years after the completion of the ST2 rail investments.

Exhibit B-6 — Cumulative Present Values of Benefits and Costs



Conclusion

This analysis shows that the anticipated quantifiable benefits from transit exceed their anticipated costs. It is important to note this analysis does not include all of the potential benefits that rail investments will contribute to region (see pages 18-22). The value of providing additional transportation capacity in new right-of-way is substantial, both for today's residents and for the continued economic growth we expect into the future.